Cassini RADAR Active Rings Processing and Calibration Activities

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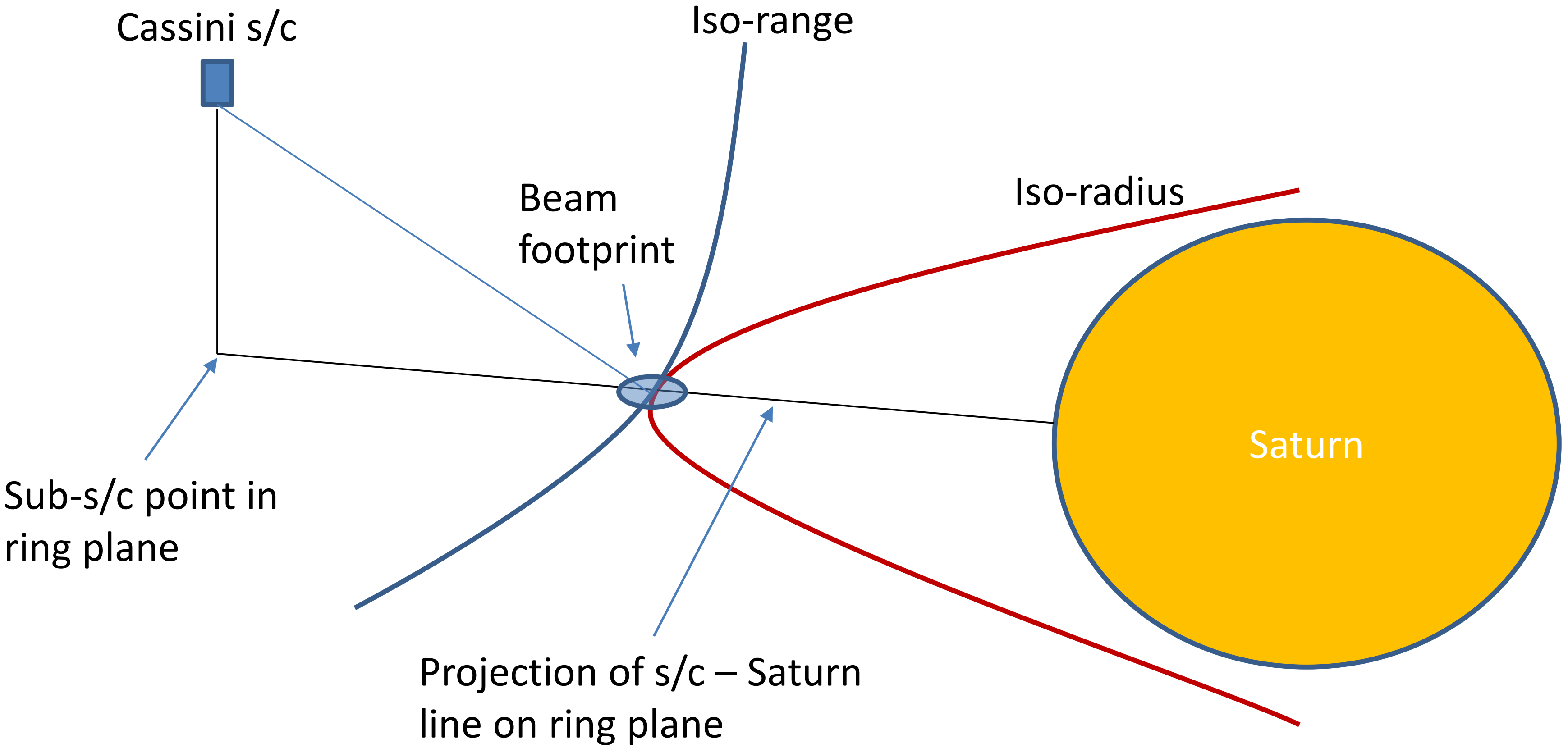
Closing Inst. Perf. Paper

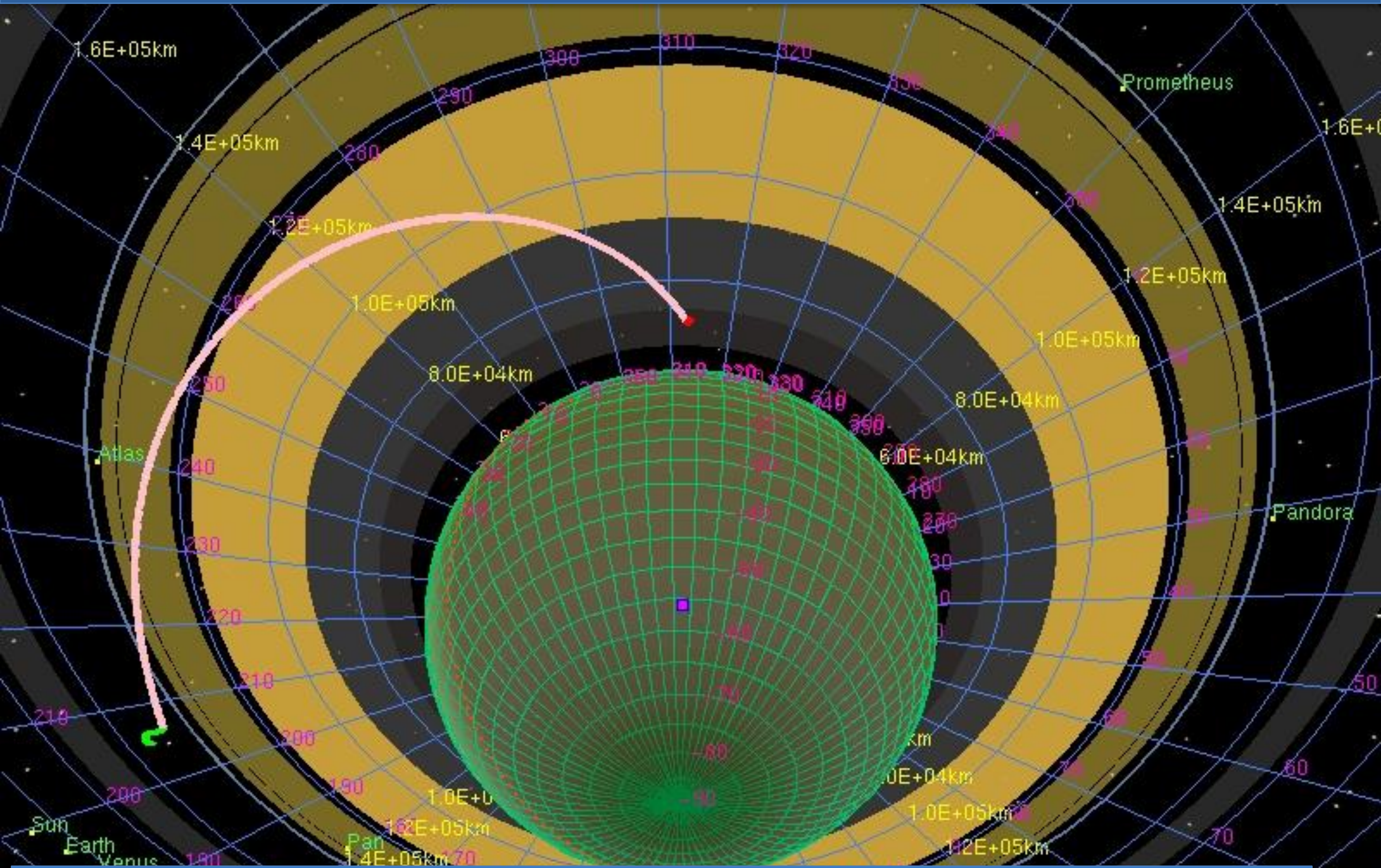
- Mission Overview
  - Describe different types of radar observations collected, updated commanding strategy discussion
- Engineering Test Summary
  - Time Variation of instrument performance
  - Updated calibration constants, relation to PDS delivered calibration
- Cross-calibrations (comparisons)?
  - SAR vs high-altitude SAR vs scatt
  - Titan vs icy satellites vs rings
  - Icy satellite updated results
- Rings data collection and calibration

Outline

- Observing geometry during radar ring scans
- Raw power data
- Real Aperture Processing and Scaling
- Real Aperture Calibrated backscatter
- Range Compression
- Range Compressed Preliminary backscatter
- Ambiguity Correction

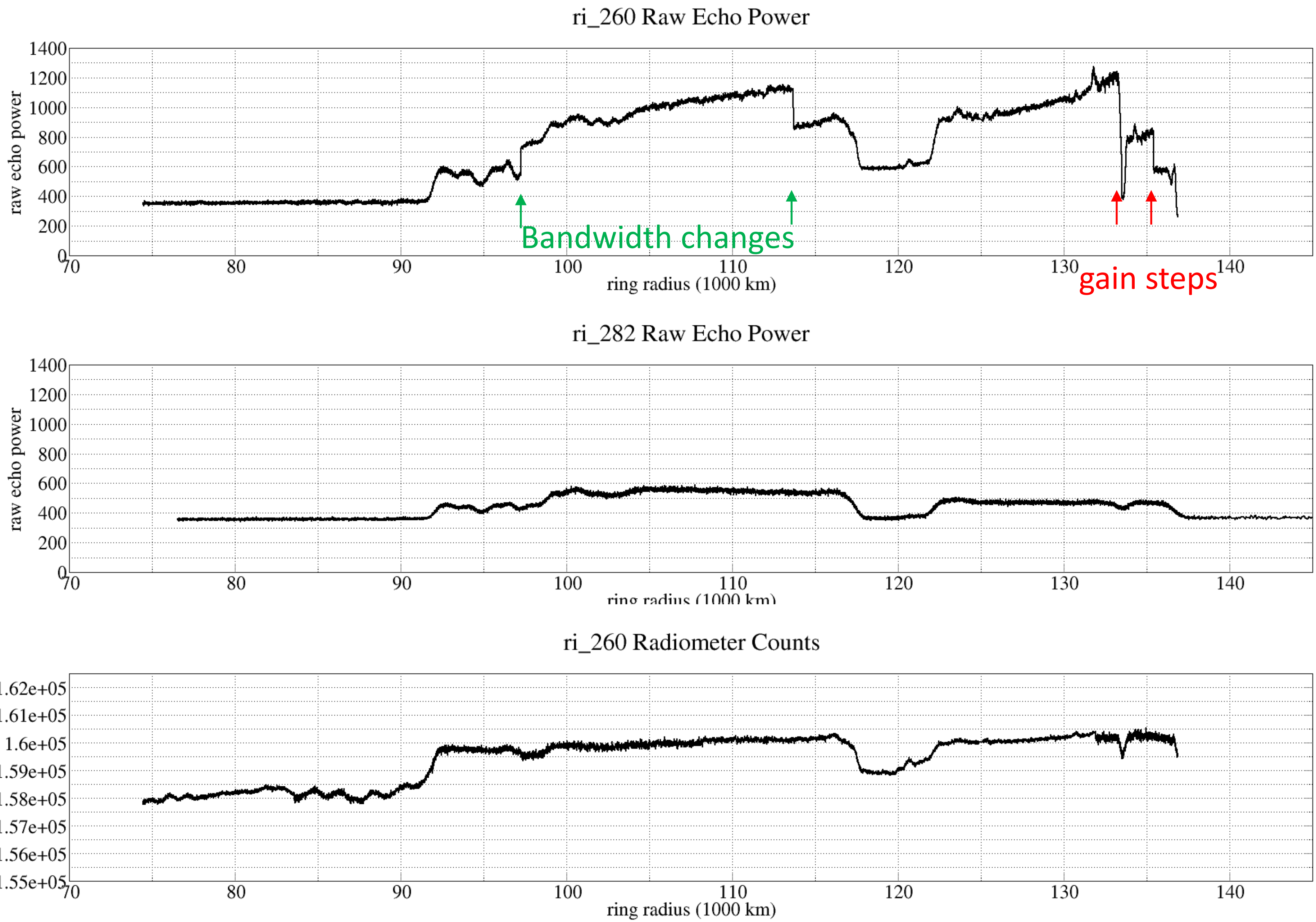
Observing Geometry




1.6E+05km
Prometheus
1.4E+05km
1.2E+05km
1.0E+05km
8.0E+04km
6.0E+04km
Atlas
Pandora
Sun
Earth
Pan

Ri_260

Uncalibrated Raw Powers From Rev 260 and Rev 282 Radar Ring Scans



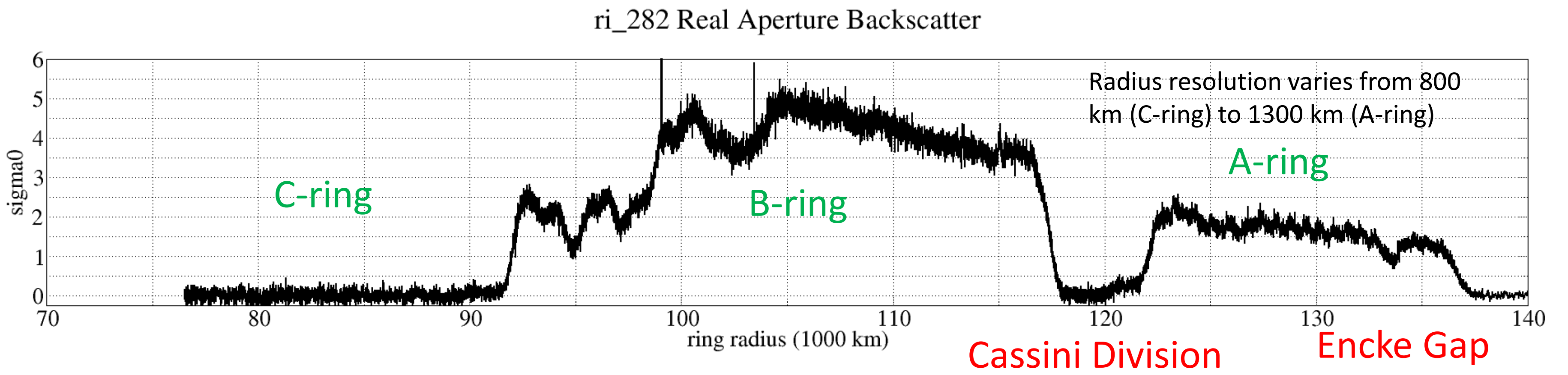
Scaling Raw Powers to Normalized Backscatter

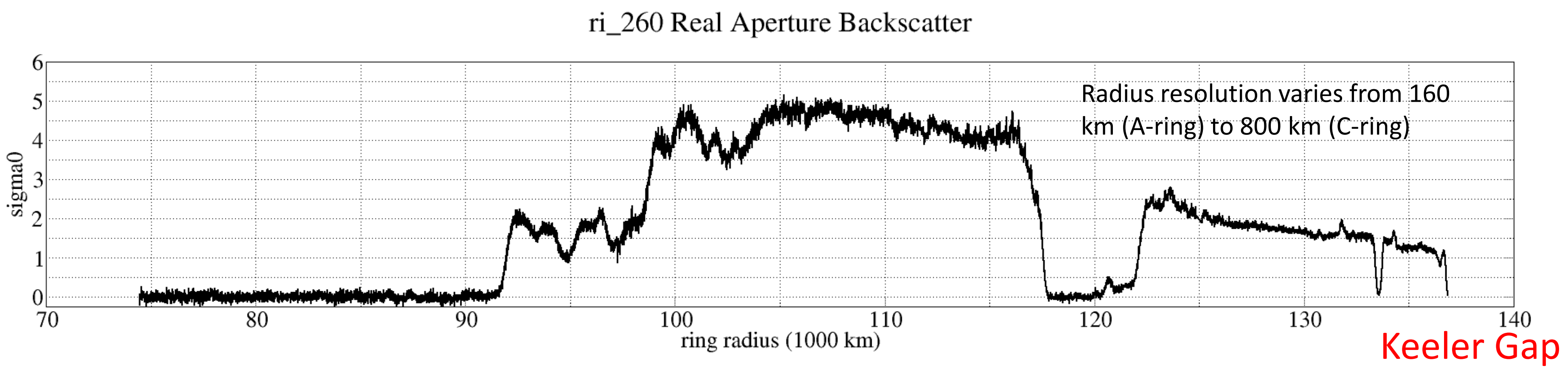
- Raw echo power in data counts
  - $V_{sn} = 1/N_{rw} \Sigma |v(i)|^2$
- Noise Subtraction
  - $V_s = V_{sn} - V_n$
- Scaling from data counts to power in Watts
  - $P_s = C V_s \quad P_n = C V_n = kT_{sys}B_{rcv}$
  - C is a calibration conversion constant which depends on the attenuator setting and bandwidth mode.
- Radar Equation relates received power to normalized backscatter cross-section σ_0
  - $P_s = \lambda^2/(4\pi)^3 \int P_t u_{rw} G^2 \sigma_0 / R^4 \, dA$

Radar Equation Details

- Rapid variation of viewing geometry and radar parameters requires detailed duty cycle correction to obtain accurate real aperture results.
- $P_s = \lambda^2/(4\pi)^3 P_{t0}\sigma_0/R^4 \int 1/N_{rw}\Sigma\Sigma p(t - i\tau_{pri}-2R/c)\, u_{rw}(t)\, G^2\, dA$
- $p(t) = 1$ for $0 < \tau < \tau_p$, 0 otherwise
- $u_{rw}(t) = 1$ for $\tau_{rwd} < \tau < \tau_{rwd} + \tau_{rw}$, 0 otherwise

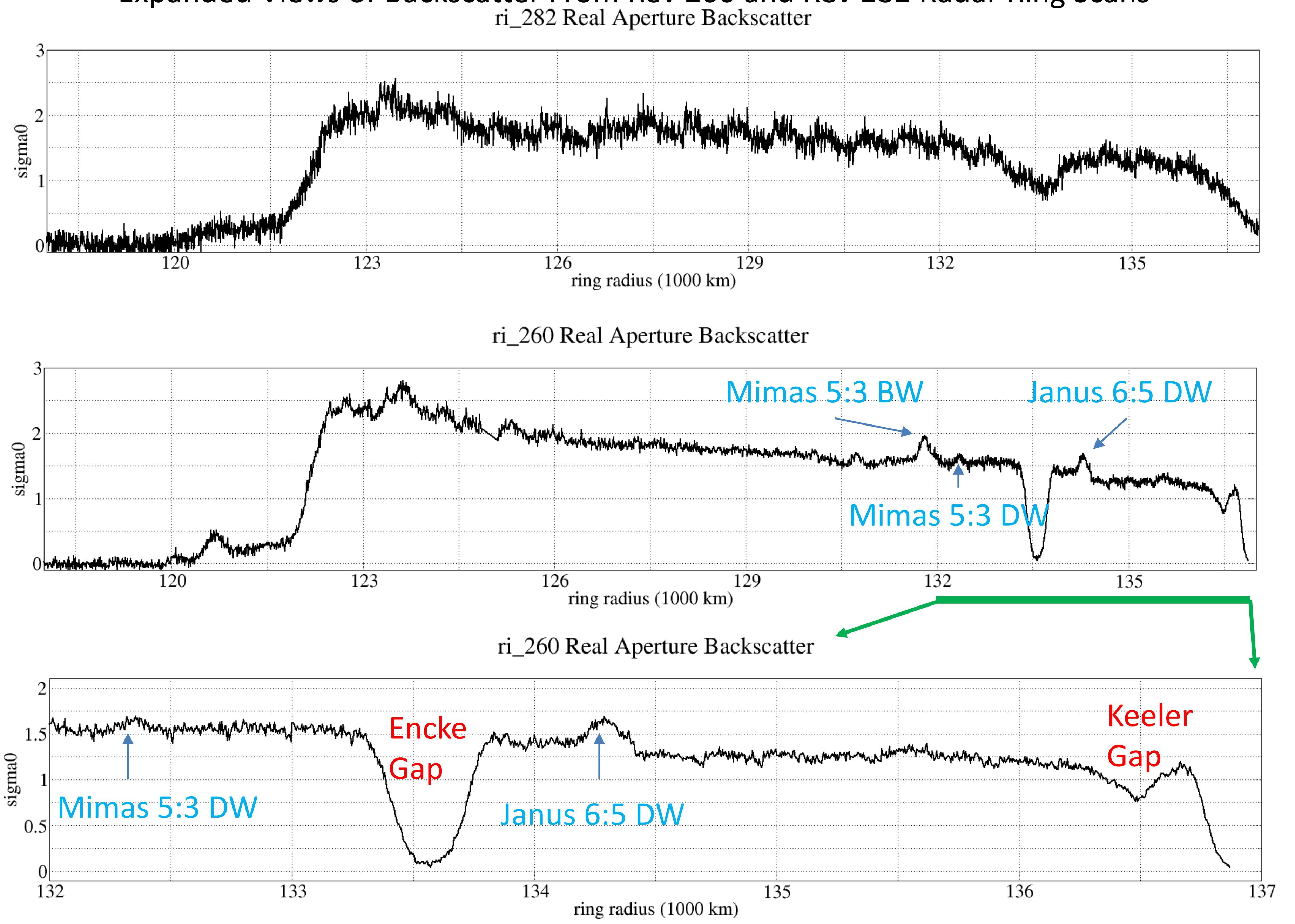
Calibrated Radar Backscatter From Rev 260 and Rev 282 Radar Ring Scans





Note: sigma0 is normalized by projected area in the ring-plane and presented here in linear units. Unity sigma0 occurs when the received power equals what an isotropic scattering area would produce.

Expanded Views of Backscatter From Rev 260 and Rev 282 Radar Ring Scans



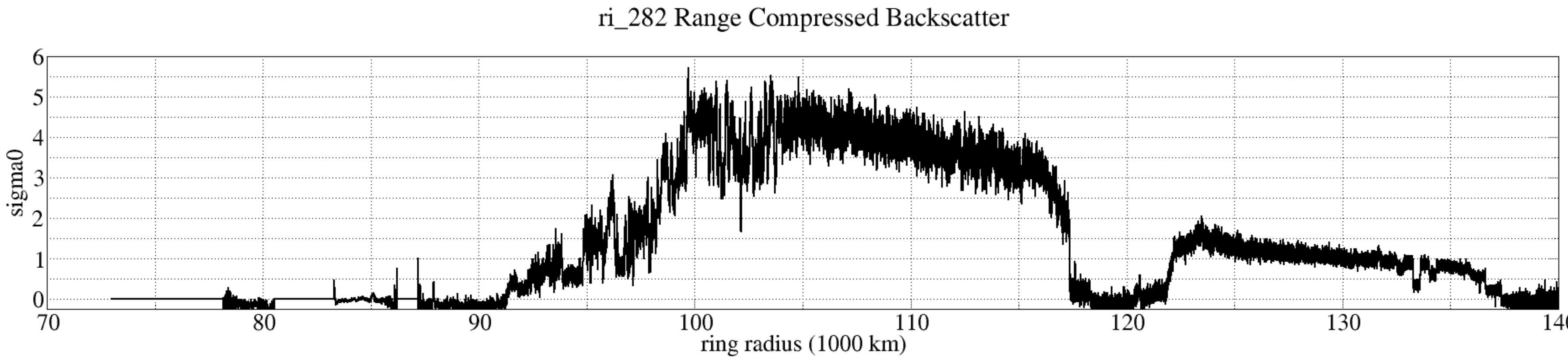
Real Aperture Summary

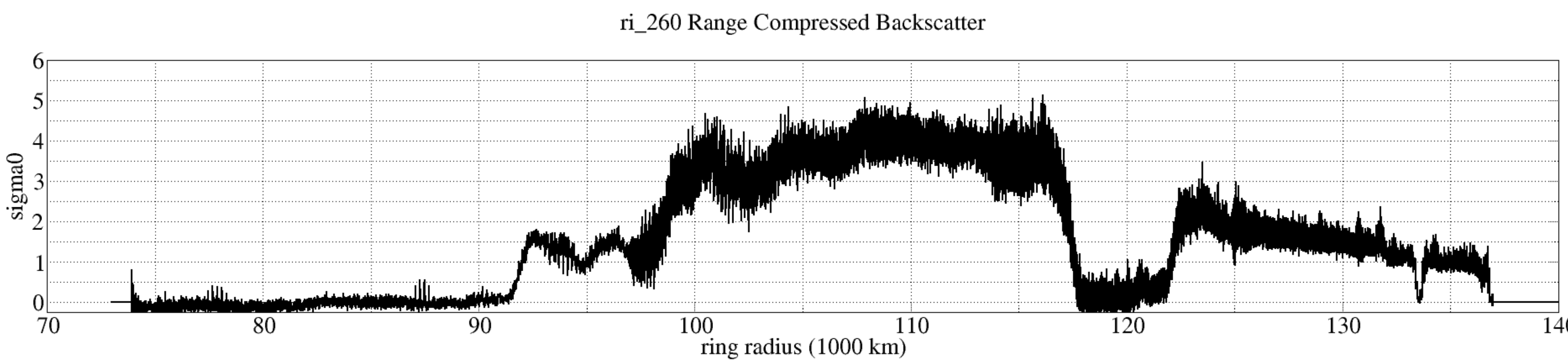
- Rapid variation of viewing geometry and radar parameters introduces some small-scale artifacts
- Consistent real aperture backscatter from ri_260 and ri_282
- Known ring features visible in radar data
- Ri_282 much lower resolution due to higher range
- Very high backscatter levels in A,B rings
  - Comparable to Xanadu on Titan and South polar region of Enceladus
  - Very low loss levels and complex dielectric structure at mm – cm scales.

Range Compression

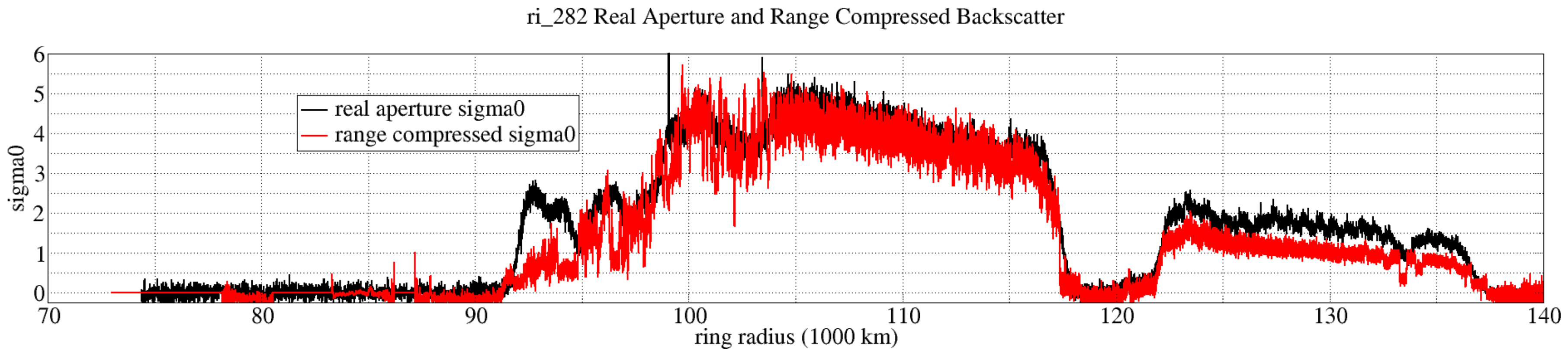
- Time domain correlation process applied to each pulse echo which illuminates a given radius bin
- Ambiguity locations (in radius) determined for each burst and included in numerical integration of the range resolution cell area
  - Needed for proper scaling to backscatter, even if no ambiguity correction is applied.
- Noise Subtraction applied using same noise level as real aperture processing.
- Scaling from data counts to power in Watts and then to backscatter uses the same parameters as for real aperture processing.
  - Numerical integrations required for accuracy
  - Radar equation numerical integrations are taken over the primary and ambiguity range bin areas rather than the whole beam main lobe footprint.

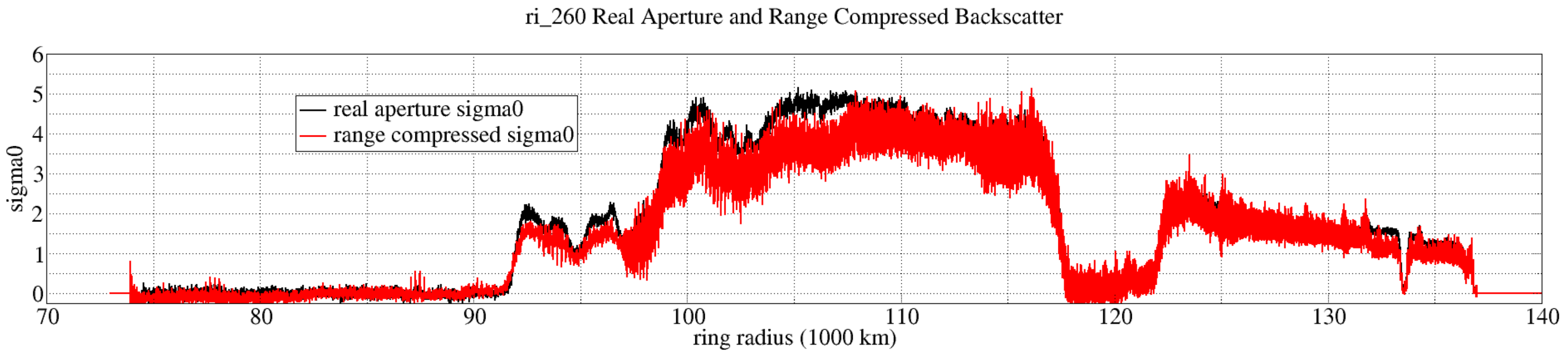
Range Compressed Backscatter



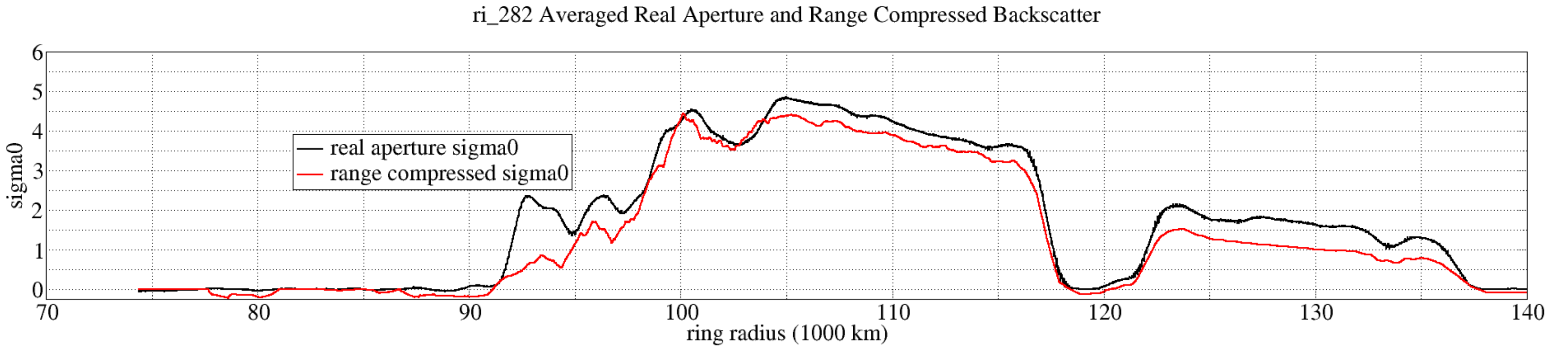


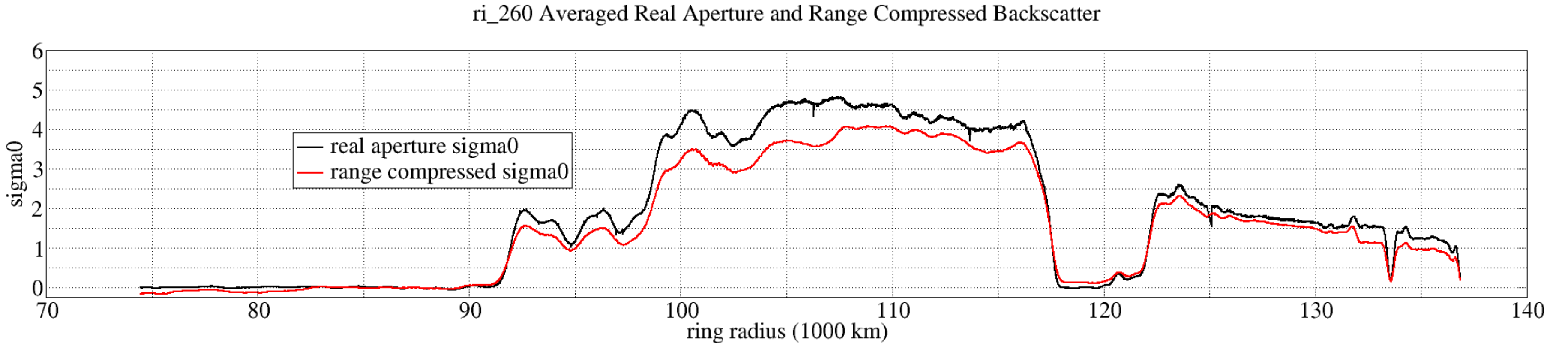
Comparison of Real Aperture and Range Compressed Backscatter





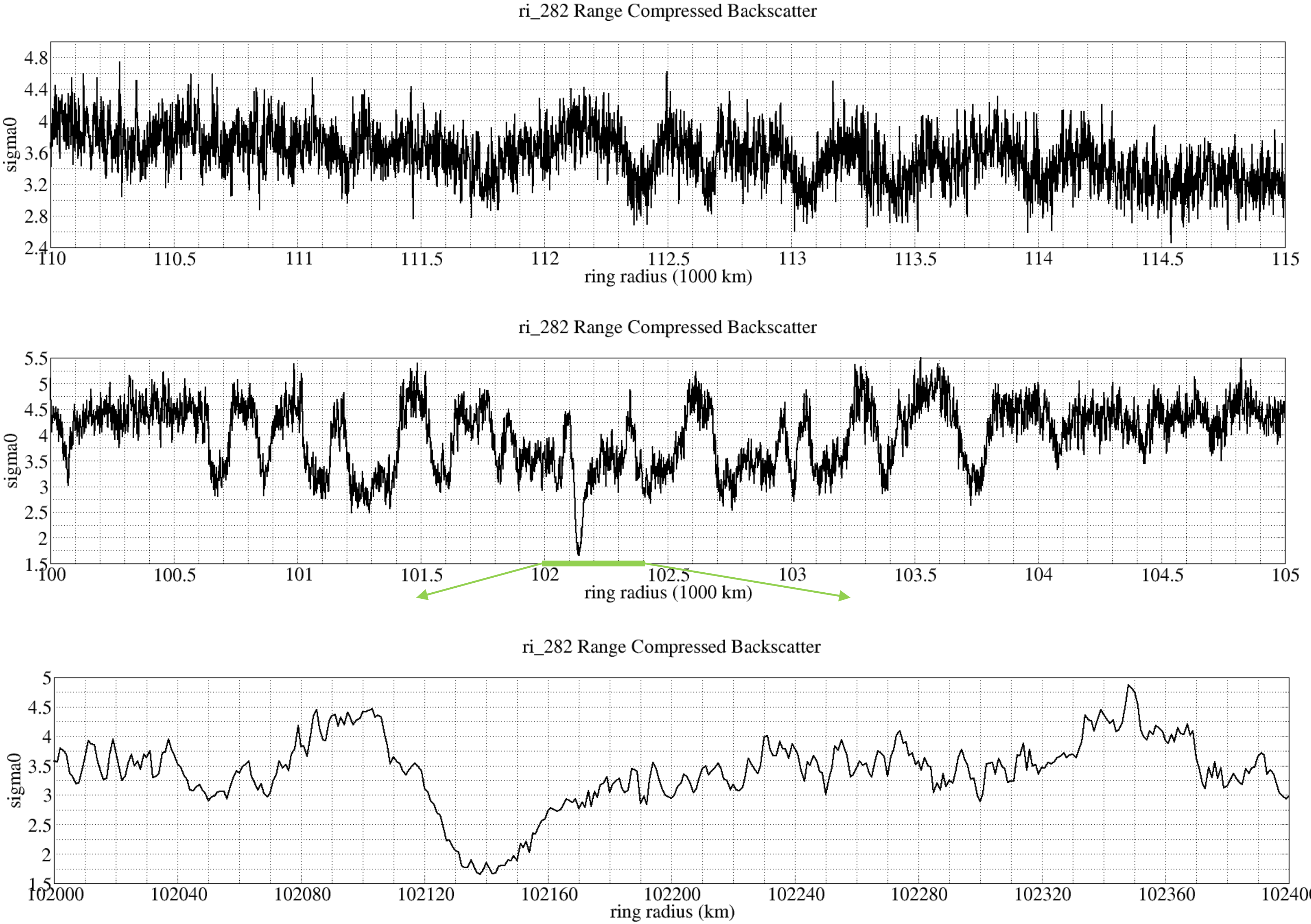
Comparison of Averaged Real Aperture and Range Compressed Backscatter





Averaging taken over the radius extent of the beam footprint.

Detail of Ri_282 Backscatter in Ambiguity Free B-ring areas



Range Compression Summary

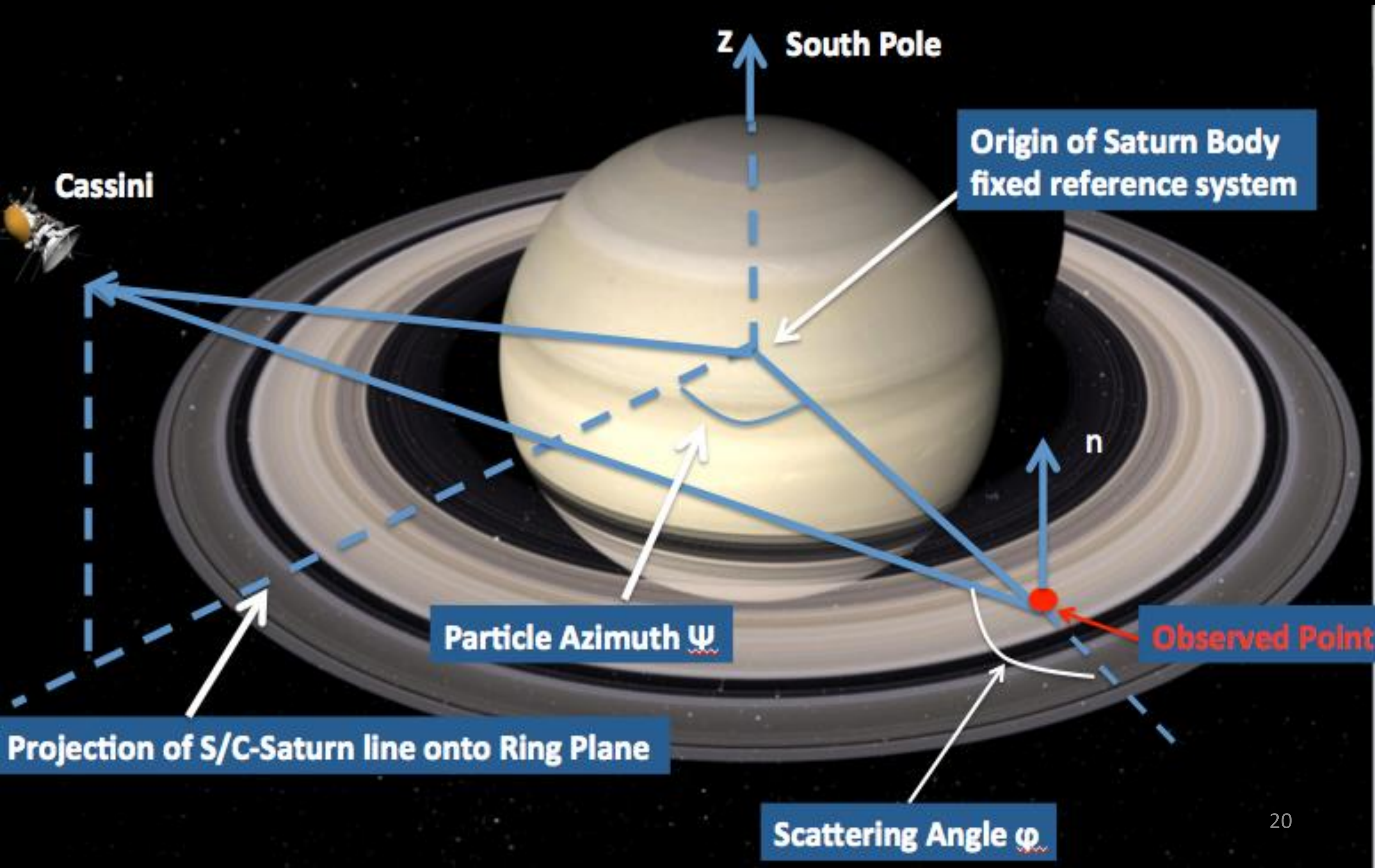
- Range compressed calibrated backscatter matches real aperture results in general form. 0.5-1 dB scaling discrepancy.
- Consistent range compressed backscatter from ri_260 and ri_282
- Known ring features visible in radar data
- Ri_282 is ambiguity free in B,C-ring areas.
- Ri_260 has range ambiguities throughout – needs ambiguity correction procedure.
- Ambiguity correction procedure in progress

Ambiguity Correction

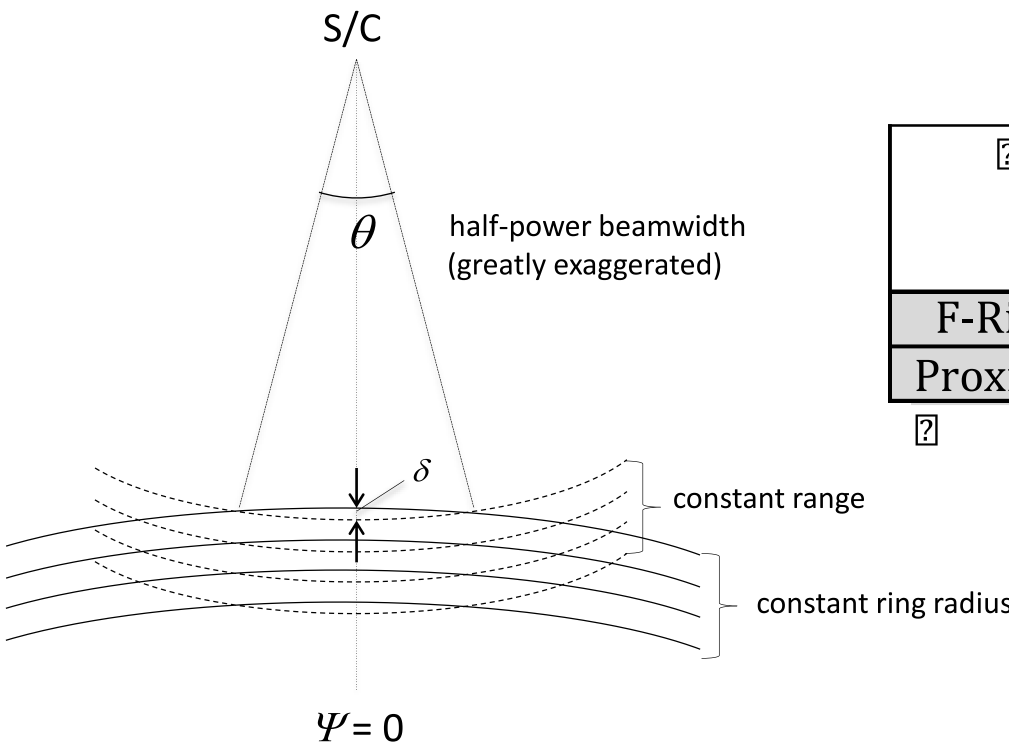
- Correlated signal power for a given radius (time delay) is the sum of echoes from a set of ambiguous radii separated by integer PRI interval and speckle noise
- $P_s(j) = n_s + \Sigma X(i,k)\sigma_0(k)$
  - burst i, pulse j, radius bin k
- Average over pulses in a burst to reduce speckle noise n_s
- Form over-determined linear system where each burst provides one equation from different parts of the antenna pattern
  - $[\langle P_s \rangle] = [[X]]\ [\sigma_0]$
- Apply singular value decomposition to solve for the $[\sigma_0]$ in least squares sense
- Algorithm needs detailed tuning with spatial (ie., radial) averaging used to reduce noise.

- Backup

Observing Geometry



1-D Range Slicing



Observing point centered at zero azimuth angle relative to spacecraft

Geometric Smearing

δ	Inner C Ring [m]	Outer A Ring [m]
F-Ring Orbit	500	75
Proximal Orbit	80	450